A NEW METHOD FOR DETERMINING THE EMPLACEMENT MECHANISM(S) OF ROCKS ON MARS. *Robert A. Craddock[1,2], L. Scott Eaton[2], Carolyn J. Russo[3], and Roy F. Torley[4];* [1]Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution, Washington, DC 20560, craddock@ceps.nasm.edu; [2]Department of Environmental Sciences, University of Virginia, Charlottesville, VA 22903; [3]Photography Department, National Air and Space Museum, Smithsonian Institution, Washington, DC 20560; [4]Department of Geological Sciences, University of Oregon, Eugene, OR 97403.

Emplacement Controversy. A variety of mechanisms have been proposed to explain the rock populations observed at the Viking landing sites. The two most commonly advocated processes include impact cratering [1, 2, 3] and in situ weathering of lava flows [1, 4, 5]. Ironically, despite attempts at landing Viking 1 in outflow channel deposits [6], a fluvial origin for the rocks seen at Chryse Planitia has only been loosely suggested [4, 7]. Similarly, the Mars Pathfinder landing site was selected to provide scientists with the opportunity to analyze a variety of material deposited by Ares Vallis [8, 9]; however, remote sensing data suggest that this area will be geologically similar to Viking 1 [8, 9, 10, 11]. Will it be clear what geologic processes have operated at the Mars Pathfinder landing site? Despite our best efforts, will we mistakenly send the rover into an area where it will only be possible to analyze rocks from one suite or one geologic process? Can we improve our chances of separating a locally derived rock (e.g., crater ejecta) from one deposited by Ares Vallis so that we obtain a sampling that is as diverse as possible?

In preparation for the Mars Pathfinder mission, rock populations have been characterized in Arizona, Hawaii, Virginia, and the Channeled Scablands of Washington State and compared to those in [12] from Tahiti. Our data suggest that it is possible to determine the most likely rock-forming mechanism(s) based on the physical characteristics of a small sampling of the rock population. Specifically, the angularity and sphericity of basaltic rocks > 64 mm in diameter can be used as indicators of their emplacement process. These observations will be important for determining the geologic history of the Mars Pathfinder landing site and interpreting Imager for Mars Pathfinder (IMP) data. They will also be useful for planning the most time- and geologically-efficient rover traverses and will support site selections for the Alpha Proton X-Ray Spectrometer (APX).

Particle Shape Analyses. The shape of a particle can be used in a general way to infer the duration of transport and the amount of reworking the particle has undergone. The term shape, however, has a complicated meaning. In general, it is used to describe the entire morphology of a particle, which includes form, angularity (i.e., roundness), and surface texture [13]. Form is related to the three principal axes of symmetry and is usually quantified in terms of sphericity, which can be used to estimate the relative distance a particle travels [14]. Angularity describes the variations in corners, edges and faces on the particle and is typically more useful for environmental interpretations [15]. For smaller particles (<64 mm), surface texture has been proven to be a useful diagnostic tool on its own. For example, beach sands often contain small V-shaped percussion marks [16]. Except for, perhaps, glacial striations, the usefulness of surface texture as a diagnostic tool for environmental process breaks down at larger particle diameters (>64 mm). In addition, surface texture on smaller diameter particles would not be visible at the resolution of Mars Pathfinder images. The remaining parameters, sphericity and angularity, can be estimated through a variety of methods using Mars Pathfinder data. Separately these parameters will probably not be useful for determining the emplacement mechanism(s) of rocks seen at the landing site. Together, however, they should allow us to discriminate between a wide variety of geologic processes, and they will increase our confidence at knowing the probable emplacement mechanism(s) of any particle rock once accurately examined.

Preliminary Results. Altogether, angularity and three dimensional measurements have already been made for over 3,000 rocks representing explosive processes analogous to impact cratering (phreatic eruptions at Halemaumau and explosions from World War II training exercises in the Kau Desert), catastrophic flooding from Pleistocene Lake Missoula (Channeled Scablands), in situ erosion of basalt flows dominated by mechanical weathering (frost shattering at the summit of Haleakala), chemical weathering (flows on the Big Island and Molokai), or both (flows in Arizona), rivers (calibrated data from Tahiti [12]), debris flows (hornfels from Virginia), and beaches (Molokai and calibrated data from Tahiti [12]). Figure 1. shows the results of these measurements compared to those estimated for the Viking landing sites [1]. Fields within this figure are explained below:

(A) The upper, glassy layer (various crossed symbols) is the outer few cm's of crust that forms on most terrestrial pahoehoe lava flows. Because rocks that erode from this material are typically flat and highly vesicular, they have a very low sphericity and angularity and seem to retain these characteristics regardless of age or amount of degradation.

(B) Rocks near the summit of Haleakala on the island of Maui (half-filled squares) have eroded from flows primarily through frost shattering, a mechanical weathering process. Because water from rain or snow melt percolates through both the irregular, polygonal fractures in the flow as well as grain-grain boundaries, frost shattering appears to lower the angularity value of the resulting rocks.

(C) The polygonal fractures that exist in pahoehoe flows result from contraction as the flow cools. "Fresh rock" (hatches) represents the blocks that form when the cooled flow is disrupted, usually by undercutting from any number of natural (e.g., gulleying) or manmade (e.g., digging) processes. These rocks showed no other signs of chemical or mechanical weathering. Interestingly, basaltic rocks from debris flows in Greene Co., Virginia (squares) and rocks emplaced by explosive processes (circles) have comparable angularity and sphericity values. These processes appear to exploit the natural weaknesses in the basalt, and the short transport distances (i.e., 100's of meters) do little to modify the angularity or sphericity. However, closer examination of the rock forms resulting from these processes may show the influence of transport distance, size of the debris flow, or the energy required to emplace a rock further away from the crater rim (data not shown).

(D) Chemical weathering (half-filled diamonds), specifically spheroidal weathering, is an important degradational process affecting most Hawaiian lava flows at lower elevations (i.e., less than ~2,000 m). Water percolating through the polygonal cooling fractures causes the blocks in the flow to disintegrate from the outside inwards. This results in a core of rock surrounded by concentric shells of weathered material. Overgrazing in parts of the Molokai Ranch has allowed heavy rains to wash most of the weathered material away, leaving behind fields of rocks that have a high angularity and high sphericity.

(E) Rocks formed near beaches generally assume a "flat" shape and have the high angularity [12]. These physical characteristics resulting from wave action are apparent from rocks examined near Kepuhi Bay, Molokai (blue cross).

(F) Rocks deposited in the Ephrata Fan during the catastrophic flooding of Pleistocene Lake Missoula (opened square) appear to fall closest to the values determined in [1] for the Viking landing sites. However, it is not immediately apparent how comparable their sphericity values are to those determined here. In addition, it is also possible to get the average values seen at the Viking landing sites by mixing rock populations from a variety of other processes. Continued research could resolve such issues.

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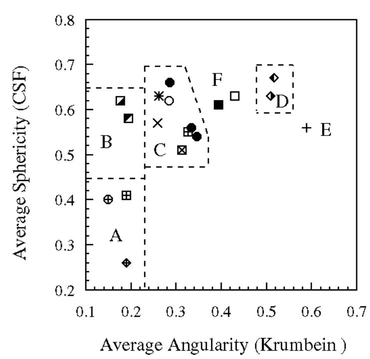

Figure 1 (right). Angularity versus sphericity for basaltic rocks >64 mm in diameter. One-sigma error bars in both the x and y directions are approximately equal to the size of the symbols used. Data fields are described in the text. "CSF" stands for the Corey Shape Factor, a method for determining a particles sphericity that relates well to its hydraulic properties. "Krumbein" refers to the visual classification chart used in determining the associated angularity.